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An Exploration of Enterprise Architecture Research

Daniel Simon
Department of Information Systems and Information Management, University of Cologne

Kai Fischbach
kai.fischbach@uni-bamberg.de

Detlef Schoder
Department of Information Systems and Information Management, University of Cologne

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Daniel Simon

Department of Information Systems and Information Management, University of Cologne

Kai Fischbach

Chair in Information Systems and Social Networks, University of Bamberg

kai.fischbach@uni-bamberg.de

Detlef Schoder

Department of Information Systems and Information Management, University of Cologne

Abstract:

Management of the enterprise architecture has become increasingly recognized as a crucial part of both business and IT management. Still, a common understanding and methodological consistency seems far from being developed. Acknowledging the significant role of research in moving the development process along, this article employs different bibliometric methods, complemented by an extensive qualitative interpretation of the research field, to provide a unique overview of the enterprise architecture literature. After answering our research questions about the collaboration via co-authorships, the intellectual structure of the research field and its most influential works, and the principal themes of research, we propose an agenda for future research based on the findings from the above analyses and their comparison to empirical insights from the literature. In particular, our study finds a considerable degree of co-authorship clustering and a positive impact of the extent of co-authorship on the diffusion of works on enterprise architecture. In addition, this article identifies three major research streams and shows that research to date has revolved around specific themes, while some of high practical relevance receive minor attention. Hence, the contribution of our study is manifold and offers support for researchers and practitioners alike.

Keywords: enterprise architecture, information technology management, survey, scientometrics

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I. INTRODUCTION

> *My opinion is, we are on the verge of seeing Enterprise Architecture "come into its own," and in the 21st Century, it will be the determining factor, the factor that separates the winners from the losers, the successful and the failures, the acquiring from the acquired, the survivors from the others* [Zachman, 1997].

The discipline of enterprise architecture (EA) has evolved enormously since John Zachman ignited its flame in 1987 [Zachman, 1987]. Approaches to enterprise architecture (including, e.g., methods, artifacts, models) have sprung up in different forms since then, driven both by practitioners and academics. In particular, several dedicated frameworks have been created [Schekkerman, 2004a], all aimed at assimilating best practices in the field of enterprise architecture. First and foremost, "The Open Group Architecture Framework" (TOGAF) [The Open Group, 2009] has garnered the most attention for its contributions within the EA arena [Buckl, Ernst, Lankes, Matthes, and Schweda, 2009b]. Nevertheless, enterprise architecture still seems to be developing on its journey to a common understanding and greater methodological consistency.

In general, enterprise architecture can be considered as a structured and aligned collection of plans for the integrated representation of the business and information technology (IT) landscape of the enterprise, in past, current, and future states [Niemann, 2006]. However, a common definition is still far from being a reality [Buckl et al., 2009b]; in fact, consistent terminology has yet to be achieved [Schönherr, 2008]. This is despite the fact that the past years have seen the creation of a considerable number of patterns [Buckl, Ernst, Lankes, and Matthes, 2008] and method building blocks [Buckl, Dierl, Matthes, and Schweda, 2010d] for EA management, which have been found useful by experienced practitioners, and the adoption of which by different enterprises to tackle similar problems [Buckl et al., 2008] may contribute to greater consistency. EA management captures all those processes, methods, tools, and responsibilities necessary to build a holistic and integrated view of the enterprise and allow for a continually aligned steering of business and IT [Matthes, Buckl, Leitel, and Schweda, 2008; Niemann, 2008]. As such, EA management deals with different architectural layers, particularly the business, information, application, and technology architectures [Platt, 2002; The Open Group, 2009].

It is widely acknowledged that EA management should be established through an enterprise-specific and -situated approach [Buckl, Schweda, and Matthes, 2010a, 2010b; Leist and Zellner, 2008; Riege and Aier, 2008]. Nevertheless, building on generally accepted standards avoids pitfalls when establishing an EA function, which, to that end, requires further substantiation and consistency of EA. At the same time, EA needs to keep up with recent developments that have become crucial in practice, such as increased cloud computing, service orientation [Stamas, 2009], and hybrid value creation [Zellner, 2008]. This may also involve a need for EA to free itself from its IT focus [Buckl et al., 2009b] and spread further into the business so it can, for example, fulfill expectations of EA management as a facilitator of strategic planning and business transformation [Aier, Riege, and Winter, 2008]. Simply put, EA practice is required to move forward to a higher maturity level. This is where research may play a crucial role [Aier et al., 2008; Langenberg and Wegmann, 2004] and where an effective review can create a firm foundation for advancing knowledge and accelerating progress [Webster and Watson, 2002] within the EA field.

To this end, this article reflects on the past and details the status quo in EA research, which is based on a few hundred contributions since the late 1980s—more than have ever been considered in any appraisal of EA research. This comprehensive picture of the entire research field is analyzed with regard to the network positions of respective authors and publications as well as to content and principal themes. Unlike in past reviews, our primary tool for exploring the state of the art is bibliometric analysis—an established tool for the structural analysis of a given research field [Culnan, 1986; Teichert and Shehu, 2010]. This allows us both to substantiate findings that have thus far been rather hypothetical (e.g., the central role of frameworks) and to produce novel insights into EA research and its interconnections. Among others, the latter includes the identification and analysis of discourses/streams in the overall research field. This is based on a sound methodological basis that provides objective [Garfield, 1979] and uniquely precise measures [Westney, 1998] for this investigation (i.e., citation data), assuming that followers build their works "on the shoulders of giants" [Merton, 1965] and use correct references (without hidden agendas) to document this recourse to the body of knowledge, and resulting in data that is not limited by a priori assumptions about prominent works (cf. Phillips and Phillips, 1998) but speaks for itself and indicates past and present research activities in the field [Garfield, Malin, and Small, 1983]. Our findings thus serve to gauge and potentially counteract tendencies of dispersion in EA research, which is consistent with calls from several academics for making different

approaches converge (e.g., Mykhashchuk, Buckl, Dierl, and Schweda, 2011; Schönherr, 2008), and also help scholars assess certain contributions in relation to developments within the overall research field.

By combining quantitative analytical approaches with an extensive qualitative interpretation of the research field, we then indicate gaps in previous EA research and, in line with the notion of "analyzing the past to prepare for the future" [Webster and Watson, 2002], provide suggestions for future research and thus complement our retrospective analysis with a prospective view of what lies ahead (cf. Schwarz, Mehta, Johnson, and Chin, 2007). In doing this, we follow the major advice with respect to state-of-the-art reviews given by Fettke [2006]: we use mathematical-statistical analysis based on a set of explicated literature and, finally, derive issues for future research.

In simple terms, our aim is to encapsulate the large body of EA literature in a way that is concise and meaningful to both researchers and practitioners. In addition to providing descriptive statistics on EA research and crediting prominent authors and publications that have helped develop the field, our review thus aims to examine the following research questions in particular:

1. How do scholars in the field collaborate via co-authorships (in comparison to other fields), and what impact does this have on the diffusion of their contributions?
2. What are the main research streams in the field, how are they interlinked, and what are the major works to be assigned to these streams?
3. How does the focus of work spread within specific dimensions of EA research content (e.g., architectural layers)?
4. Based on the insights gained through the answers to the aforementioned questions (compared to main concerns of EA practice as documented in the literature), what are the opportunities for key contributions in the future and what measures can be taken to achieve further progress in the field?

The remainder of this article is structured as follows. The next section surveys past research on the state of enterprise architecture in the literature and in practice. The subsequent section is the central part of this work: we apply co-author, citation, co-citation (based on multivariate statistical and social network analysis methods), and content analysis to more than 600 research documents, exploring the state of the art through a combination of these different bibliometric and qualitative methods. By doing this, we derive answers to our first three research questions. The penultimate section builds on our analysis and turns to our fourth research question. It consolidates our previous results and, complemented by findings from the literature, charts the territory for future EA research. The article's final section summarizes our findings and "take-home messages" [Bem, 1995], which researchers and practitioners alike may find beneficial, and discusses potential further reviews of EA literature.

II. RELATED WORK

Several researchers have discussed the state of enterprise architecture in literature and practice. These reviews are generally different in their scope. Some concentrate on EA frameworks, some deal with both EA literature and practice, and others focus on either literature or practice specifically. Schekkermann [2004a] and Schönherr [2004], for example, provide detailed overviews of existing EA frameworks. Similarly, Esswein and Weiler [2008] compare different EA frameworks and emphasize their broad and comprehensive character, concluding that architectural methods need to be integrated closer with related methods, such as those from business process management. Leist and Zellner [2006] go further and propose different requirements that current architecture frameworks should meet to enable developing, describing, and maintaining an enterprise architecture. Their evaluation of some well-known frameworks concludes that these have different strengths and that, in general, there are several areas for methodological improvement.

Aier et al. [2008] provide an overview of EA literature (including frameworks), comparing different approaches found in the literature along the following criteria: the understanding of enterprise architecture (i.e., the degree of consideration of architectural layers); the representation of enterprise architecture (modeling languages, tool support); and the use of enterprise architecture (e.g., documentation, analysis, and planning). They also explore the state of enterprise architecture in practice. Their empirical study (based on sixty-one answered questionnaires) reveals that the EA function typically is embedded in the IT organization rather than in business management. Further, they show that applications, interfaces, data structures, projects, business goals, and software, network, and hardware components are the elements that most often find their way into enterprise architecture. In contrast, essential elements of a company's business model such as distribution channels, market segments, and the interaction with suppliers are found to be of lower significance and not equally represented in enterprise architecture.

The Aier et al. [2008] findings are mainly in line with Schönherr [2008], who analyzes a total of 126 references seeking common EA terminology and finds that more contributions in the EA field focus on the organization layer (as a sublayer of business architecture covering, e.g., business processes and organizational structure) and the application architecture rather than, for example, the strategy layer (as the second sublayer of business architecture). Langenberg and Wegmann [2004] also provide an evaluation of EA research, analyzing eighty papers; they find that far more researchers concentrate on the use of enterprise architecture (EA benefits/drivers, EA experiences, EA use in other disciplines) than on, say, frameworks and modeling issues. Among the frameworks, Zachman [1987] is the one referenced most often up to 2004, after which Buckl et al. [2009b] conclude that "The Open Group Architecture Framework" (TOGAF) has become the most prominent approach in practice.

Kappelman, McGinnis, Pettite, and Sidorova [2008] survey IT professionals to capture key functions and benefits of enterprise architecture. The great majority of respondents agree that EA provides a blueprint of the organization and also consider EA a tool for organizational planning. However, Winter, Buckl, Matthes, and Schweda [2010], in a more recent publication, illustrate that a great proportion of EA practices document only the as-is enterprise architecture. Business-IT-alignment is found to be the EA management goal of greatest importance. Schmidt and Buxmann [2011] search success determinants of EA management and find architecture governance to be the most important factor. Stakeholder participation and communication are identified to be of somewhat less importance.

While EA research and practice has been the subject of regular reviews, investigations of the state of the art in EA research do not provide a broad picture. First, these studies focus on only a specific fraction of the EA literature, e.g., on frameworks, or on works of specific research groups, or of those presented at certain conferences, although a complete review should generally not be confined to specific, potentially "top" publications [Webster and Watson, 2002]. Second, the analysis of the sources considered stops short of dealing with some of the core aspects of enterprise architecture in detail, such as architectural processes, the EA meta model (as the conceptual scheme of EA content) [Niemann, 2008], and the understanding of business architecture. Third, there is no work that actually looks into the network of EA research to allow for a well-founded identification of certain research streams and of those contributions that are particularly significant.

Schelp and Winter [2009] is one of the very few studies that identify different language communities in EA research. In a recent work, Mykhashchuk et al. [2011] investigate EA literature in terms of the temporal and regional distribution of publications, the number of references of these publications and the involved author groups to provide an overview of the current research occupation in the field of EA management. Among others, they find out that the most productive research groups are from Europe and that European scientists and practitioners seem to have taken over thought leadership in the field. Lucke, Krell, and Lechner [2010] also review the existing literature and identify critical issues in enterprise architecting by applying content analysis to seventy-one articles. Absent an in-depth investigation of the underlying network, though, these studies do not take advantage of a firmer foundation upon which to derive actual (and potentially invisible) discourses of major importance and achieve a common basis for future research. As Small and Griffith [1974] state in their pioneering work, "most scientists have intuitive notions about the subdivisions of their fields, but no observer, however broadly trained, can gain an overall perspective on the scientific mosaic." In the analysis of EA research, we thus can learn from what has already become common in that of other research fields that build on different bibliometric methods, and from their use of the combined judgment of a large number of experts in the field, to examine the state of the art (see Table 1; further references include White and McCain [1998], Culnan [1986], and Cockcroft [2010]).

III. AN EXTENSIVE ANALYSIS OF EA RESEARCH

To provide a solid basis for a state-of-the-art analysis, we performed an extensive search for EA literature (which we here make transparent following the guidelines of vom Brocke et al. [2009]) using Google Scholar, the EBSCO Business Source Complete database, the AIS Electronic Library, the IEEE and ACM literature portals, and simple Google Web searches. In doing this, we followed the approach of, for example, Culnan [1987], Charvet, Cooper, and Gardner [2008], and Uysal [2010], rather than relying on a previously defined sample of journals or documents. Our inquiry focused on the explicit use of the term *enterprise architecture,* its German equivalent *Unternehmensarchitektur* (to account for the German-language research groups found by Schelp and Winter [2009] to be particular relevant), and related terms for enterprise architectural subsets (*business architecture, process architecture, information systems architecture, IT architecture, IT landscape, information architecture, data architecture, application architecture, application landscape, integration architecture, technology architecture, infrastructure architecture)* either in a document's title, abstract, or body text. A single instance of such terms was considered insufficient to add the document to our analysis, so each such document was examined to verify that it was genuinely about enterprise architecture.

Assuming that practitioners also play an important role in EA research [Aier et al., 2008], we did not limit our search to scientific publications. We also considered several practitioner contributions (e.g., Beveridge and Perks, 2002;

Dern, 2006; Engels et al., 2008; Hanschke, 2010; Niemann, 2006; Schekkerman, 2004a), but excluded marketing material or other documents without references; thus, we did not include consultant and tool vendor "white papers" in our analysis. Instead, we considered English- and German-language journal articles, conference papers, books, book sections (that could be attributed to specific authors and included a dedicated reference section), and academic reports. In total, we identified 608 publications related to enterprise architecture published from 1987 to 2010 (9.5 percent in German), which we included in our analysis; however, we are aware that EA concepts may have already existed before, coined differently though (an inclusion of such research may have blurred the results of our study on designated EA research). Figure 1 shows the number of publications per year (but excludes 2010, since our document collection was in mid-2010 and thus did not yield an exhaustive list for that year).

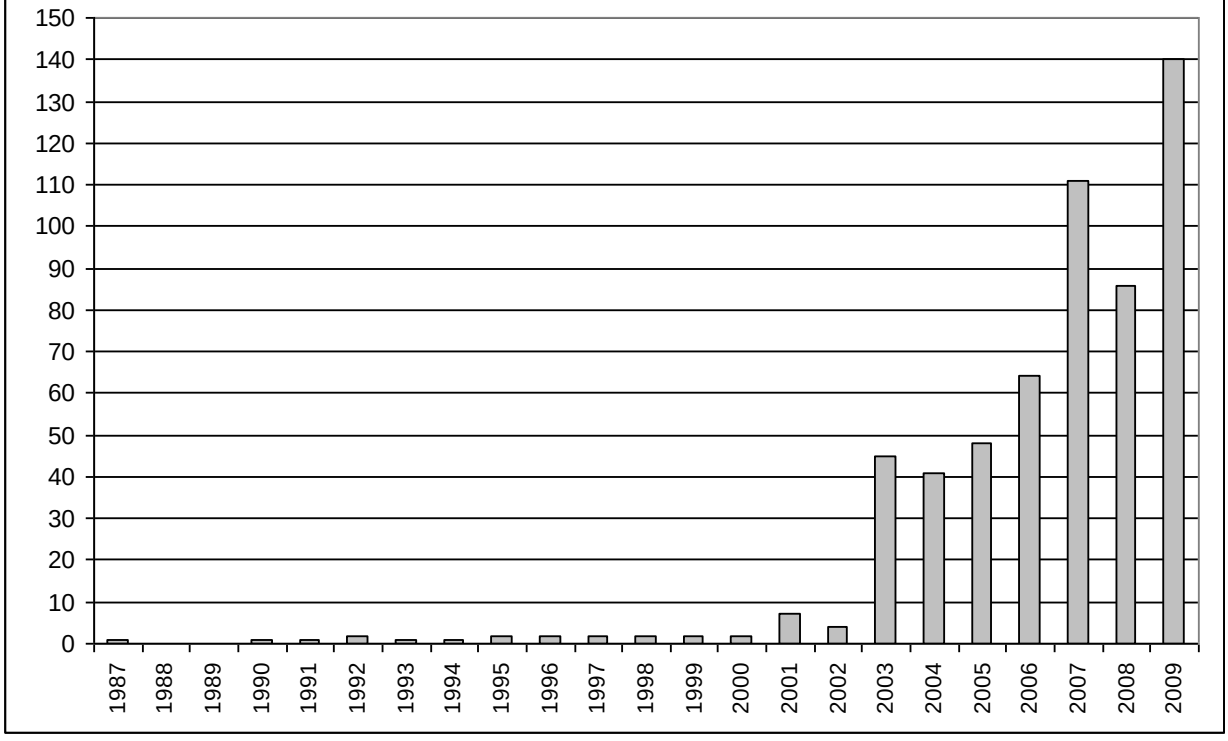

Figure 1. Number of Included Publications per Year

These publications were input into a database that captured title, author(s), year of publication, and any references to other source documents we included. In addition, we collected a sample set of publications in related research areas to allow for an indication of the degree to which EA literature is linked to related fields and draws upon lessons learned in these areas, given the interdisciplinary character (cf. Webster and Watson, 2002) of the EA field. Our selection of related research fields was based on the management practices with which EA management has major touch points and with which it must be coordinated primarily, according to TOGAF [The Open Group, 2009]: business planning/business capability management, portfolio/project management, solution development, and operations management. Therefore, we included works from the following research fields (using associated search terms): strategic management/business engineering (including organizational management and business process management) (54), IT portfolio management (57), software/solution architecture (61), and enterprise application integration (as the field associated with operations management, which integrates and sustains deliverables within the corporate infrastructure [The Open Group, 2009]) (9). In addition, we included works from the research field of enterprise modeling/enterprise ontology (56), acknowledging that it shares fundamental ideas with enterprise architecture and similarly deals with conceptual enterprise models (cf. Dietz and Hoogervorst, 2008; Frank, 2002).

Aware that the above selection is not exhaustive and certain fields potentially associated with enterprise architecture may be missing, we drew the line there and did not include other fields (see Appendix A for the bibliography of included documents). In particular, this was to maintain a definite and managable scope for analysis and to avoid adding noise and unlimited scope increase given the variety of concerns close to enterprise architecture. Service-oriented architecture, for example, would have definitely been another reasonable field for inclusion. However, since this represents a specific architectural concept, we would have equally needed to consider the fields of cloud computing, virtualization, and interoperability, for example. As a result, the references of each EA core document were extended with respect to the additional works from the above fields.

From the resulting data set, we generated three files (in both dl- and gefx-format), which were imported into UCINET 6, and Gephi 0.7, an open-source software tool for graph and network analysis that has been used successfully for semantic network case studies and social network analysis several times before [Bastian, Heymann, and Jacomy, 2009]. These files represented three different networks to be analyzed: co-authorship, document citation, and document co-citation.

The co-authorship network was supposed to provide the basis for exploring research collaboration [Liu, Bollen, Nelson, and Van de Sompel, 2005] within the vast terrain of enterprise architecture, since it basically shows what authors (nodes) publish with one another (represented by an edge in the network graph) and in what frequency (captured by the edge's weight). Since co-authorship represents a considerable indicator of collaboration [Glänzel and Schubert, 2004], the corresponding network may allow the identification of EA research communities. In addition, we were interested in how this was mirrored in the second network created—the document citation network. We speculated that potential differences in the focus of EA research might lead us to find isolated individuals in the co-authorship network who may nevertheless have made significant EA contributions as per their corresponding positions in the document citation network.

Citation networks generally exist in three different forms: journal citation, author citation, and document citation. Our focus on the citation network at the level of single publications [Teichert and Shehu, 2010] rather than on the aggregated journal or author level was so we could gauge the importance of single publications in the field, based on our careful selection of a sufficiently large sample (cf. Pilkington and Fitzgerald, 2006; Pilkington and Meredith, 2009). This is because frequently cited documents are likely to exert a stronger influence on a discipline than those less frequently cited [Teichert and Shehu, 2010], based on the rationale that articles tend to be cited when considered essential in supporting certain arguments. In fact, Case and Higgins [2000] have shown that critical citations are rather rare. Despite controversial discussions around the most appropriate measure of a publication's quality [Abramo, D'Angelo, and Di Costa, 2010], we thus follow the general assertion and common agreement that the number of received citations reflect a document's influence and, therefore, quality [Acedo, Barroso, Casanueva, and Galán, 2006; Wade, 1975]. The use of the main alternative indicator of quality, the journal impact factor, may have caused great difficulties in analysis due to the fact that such an impact factor does not exist for every journal and document type [Abramo et al., 2010; Dolfsma and Leydesdorff, 2010] and that our set of documents contains various books and book chapters for which such values also do not exist. Eventually, our focus on the document citation network also was supposed to provide a first indication of the existence of potential clusters around certain themes within EA research.

We made use of the co-citation network to take this even further and delve more deeply into the analysis regarding major research topics [Teichert and Shehu, 2009]. Basically, this mirrors the frequency with which two documents are cited together [Small, 1973]. As such, it is a complementary method to bibliographic coupling, which focuses on the sharing of one or more references between two documents [Small, 1973]. Again, we worked with the document co-citation network rather than the author co-citation network, although the latter is the one employed more often. However, we drew upon the fact that document co-citation analysis entails more biographical detail and precision and is a more direct way of assessing contributions to several research topics [Teichert and Shehu, 2010; Uysal, 2010]. In general, co-citation analysis is considered a technique to map the intellectual structure of a research domain by building on "the empirical consensus of hundreds of citers rather than the impressions of individuals" [White, 1990] and thereby identifying "invisible colleges" [Culnan, 1987] of research, with the most influential documents and the relational links between those documents [Teichert and Shehu, 2010; Uysal, 2010]. Ultimately, this may reveal "schools of thought" within a given field [Teichert and Shehu, 2009].

We applied a valuable tool for analyzing such networks [Oinas-Kokkonen, Lyytinen, and Yoo, 2010; Uysal, 2010]—social network analysis (SNA). Rooted in graph theory, SNA conceptualizes and visualizes structures that emerge from any interaction or connection as networks and allows a quantitative analysis of the relationships of the network's nodes [Cockcroft, 2010; Otte, 2002]. As such, it brings two main perspectives to the study of a research field: (1) the structural patterns of scientific collaboration/themes and (2) the distinctive position of an actor/study in the overall field, assuming that these reflect the dissemination of knowledge and a certain quality of contribution. In this study, we thus used different centrality measures to examine both the role of individual authors/publications within the overall network (micro level) and the characteristics of the network as a whole (macro level). Representing the number of relations a given node maintains [Dolfsma and Leydesdorff, 2010], degree centrality was used to measure the centrality and power of authors and EA contributions within the research field [Uysal, 2010]. Betweenness centrality, that is, the "number of shortest paths that pass through a given node" [Otte, 2002], was the measure for evaluating the node's "interdisciplinarity" [Dolfsma and Leydesdorff, 2010; Leydesdorff, 2007], indicating whether the author/document plays a bridging role in the network. Further, we employed closeness centrality to measure the "distance" of an author/document to other nodes in the network [Dolfsma and Leydesdorff, 2010] and eigenvector centrality to quantify the extent to which nodes are connected to other central nodes [Bonacich, 2007;

Costenbader and Valente, 2003]. Rounding out the network measures, we used overall graph density and modularity (as the number of edges falling within groups minus the expected number in an equivalent network with edges placed at random) [Newman, 2006], average path length (average number of intermediaries between all pairs of nodes), and clustering coefficient (average fraction of a node's neighbors who are also neighbors of one another) [Uzzi and Spiro, 2005].

Table 1: Use of Bibliometric Methods in Other Research Fields

Reference	Analyzed research field	Used bibliometric method	Findings
Acedo et al. [2006]	Management, organization	Co-authorship analysis using degree and betweenness centralities, clustering coefficient and network density	• Co-authorship characteristics differ significantly from those in natural sciences with respect to main descriptors such as local clustering (found to be high) • Multi-authored papers are likely to be cited more often than single-authored.
Chuo and Tseng [2010]	Tourism	Author citation analysis using degree centralities, author co-citation analysis using cluster and factor analysis	• Most influential publications according to degree centralities • Existence of research concentrations, e.g., impact of tourism and social aspects and authenticity of tourism, and a new focus on tourism demand forecasting
Culnan [1987]	Management information systems (MIS) (1980–1985)	Author co-citation analysis using factor analysis	• Different intellectual clusters of research, e.g., foundations, MIS management, organizational approaches to MIS design and use, MIS curriculum • MIS research shifted from a technological to an organizational and managerial focus. • Publications assumed to be influential did not always prove to be so, according to the actual citation patterns.
Lin and Cheng [2010]	Strategic alliance	Document co-citation analysis using factor analysis and network visualization	• Three main research themes: strategic alliance formation, learning and absorptive capability, relationships and characteristics of partnership success
Phillips and Phillips [1998]	Business logistics and transportation	Journal citation analysis using degree and betweenness centralities, multi-dimensional scaling and cluster analysis	• Central journals according to degree and betweenness scores • Groupings of journals according to multivariate statistics, revealing that a distinct break between business logistics and transportation disappeared over time
Teichert and Shehu [2009, 2010]	Conjoint analysis (CA)	Document citation analysis using degree centralities, document co-citation analysis using factor analysis and multidimensional scaling	• Major research contributions (as per citation scores) • Existence of seven research streams (through factor analysis), e.g., traditional CA for marketing applications, health care, and empirical CA, with close links between the streams (visualized via multidimensional scaling)
Uysal [2010]	Business Ethics	Document co-citation analysis using multidimensional scaling and degree, betweenness and closeness centralities	• Core documents (as represented by degree, betweenness and closeness centralities) • Existence of four research clusters (based on co-citations profiles visualized via multidimensional scaling)

In addition to these SNA techniques, we applied multivariate statistical methods to the co-citation network. This comprised factor and multidimensional scaling analysis, both of which are typically used in such bibliographic studies, as they have been proven suitable for identifying and interpreting themes and their relationships and mapping a research field's intellectual structure [Teichert and Shehu, 2010; Uysal, 2010]. To that end, we compiled a co-citation matrix of the thirty-seven most-cited core papers (all with more than twenty citations), representing the top 6 percent of cited papers (cf. Charvet et al., 2008; Teichert and Shehu, 2010). In line with White and Griffith [1981], we replaced the diagonal elements of this matrix by the sum of the three highest scores, divided by two (cf.

Ahlgren, 2003). We exported this matrix of raw data to SPSS to allow for multivariate analysis. Table 1 provides an overview of some main findings gained by the use of the above bibliometric methods to examine the state of the art in other research fields.

To draw as detailed a picture as possible of the EA research landscape, we complemented these network analyses with an in-depth content analysis of the 608 EA core documents, given the scientific standing attributed to this technique [Kassarjan, 1977]. Following the guidelines of Bem [1995] that such a review should be based on an adequate structure of the topic, we rated the documents' focus (cf. Lucke et al., 2010) with respect to EA layers, EA methodology, EA management tasks/processes, and EA lifecycle phases. This was to bring different perspectives into the analysis: ontological (the architecural content that is dealt with, as represented by respective EA layers); methodical (the method elements (cf. Leist and Zellner, 2006) in scope, e.g., procedures or roles); operating (the EA management tasks/processes studied); and functional (the basic architectural activities in scope, as captured by the general phases of the EA management cycle). Given that our examination did not deal with "highly latent" [Neuendorf, 2002] constructs, the potential subjectivity of content interpretation is not a critical concern in our analysis (cf. Potter and Levine-Donnerstein, 1999). Consequently, the results of our content analysis can be considered reliable, shedding light on whether research revolves around certain architectural layers, for example, and whether others remain entrenched in the background of research.

The results of our co-authorship, citation, co-citation, and content analysis follow.

Co-authorship Analysis

The co-authorship network comprises 752 nodes and 1549 edges. The average degree centrality is 2.06, indicating a rather low level of research collaboration throughout the EA author network. More specifically, it denotes moderate collaborative work across different university research groups, since most groups are likely to be of a greater size and collaboration is considered to occur primarily within the research groups themselves, mirrored by the average clustering coefficient (average fraction of an author's collaborators who are also collaborators with one another) of 0.608. This is a high value compared to other (potentially more established) fields, as Table 2 reveals. In fact, the networks studied by Newman [2001] and Acedo et al. [2006], although different in size, timeframe, and databases used, show a lower trend toward small groups than the EA network, except the management network. The lack of collaboration is evidenced by the overall graph density (indicator for the level of connectedness of a network) of 0.005 and the graph modularity (which can be either positive or negative, with a large positive value indicating the presence of community structure) of 0.838, suggesting a rather fragmented overall picture.

Table 2: Characteristics of the Co-authorship Network Compared to Other Fields

	EA	IT	Management and organization	Physics	Medicine
Authors	752	11.994	10.176	52.909	1.520.251
Authors per document	2.66	2.22	1.88	2.53	3.75
Clustering coefficient	0.608	0.496	0.681	0.430	0.066

Applying the algorithm of Fruchterman and Reingold [1991] allowed us to come to an untangled placement of nodes and thus visualize clusters within the overall network graph. This picture became even more clear when filtering nodes by a minimum degree of 10. As a result, we found one singleton and two pairs of nodes, one of which represents the works of the Technical University of Lisbon. We also found two clusters of at least three nodes. One is a clique—a subgraph in which any node is directly connected to any other node [Otte and Rousseau, 2002]—comprising those authors who have worked collaboratively on the research of Lankhorst et al. [2005]. This is where we found close resemblance to "Collaborative Innovation Networks" (COINs), "groups of self-motivated individuals from various parts of an organization or from multiple organizations … who work together on a new idea, driven by a common vision" [Gloor, Laubacher, Dynes, and Zhao, 2003]. Interestingly, the authors in this cluster also possess the greatest eigenvector centrality scores within the overall network.

The second cluster comprises researchers at the Technical University of Munich, the University of St. Gallen, the Technical University of Berlin, and the KTH Royal Institute of Technology in Stockholm. It is thus made up of clique-like structures loosely tied to one another. Although there is some degree of collaboration between these major research groups within the EA field [Schelp and Winter, 2009], COIN-related criteria are far from met. In addition, collaboration may not be analyzed comprehensively by concentrating only on the number of neighbors (i.e., on whether there is any collaboration at all) and weighing every "contact" equally [Bonacich, 2007].

For this reason, we also calculated eigenvector centrality (see above). Moreover, we looked into the edge's weight to account for the frequency of collaboration (note that there may be a certain interdependency with the document

outlets, which may determine the required efforts to complete publication and thus the available capacity for other research projects). Consequently, we filtered the graph's edges by a minimum weight of 5 (i.e., five joint contributions of two individual authors), and then used the resulting graph and removed all isolated nodes (i.e., nodes without any edges remaining). In doing so, we arrived at a picture of the main research groups and the inherent strong ties, but any connections between them basically were lost (see Figure 2; an edge's width represents its weight). Notably, the use of a minimum weight of 3 yielded similar results. Against this background, a coherent research community with regular collaboration (at the authorship level) still appears to be in its infancy. This is due in particular to the moderate weight of the weak ties between different groups; these weak ties can provide access to nonredundant information. This is astonishing, given the diverse and skill-demanding nature of the EA discipline [Lucke et al., 2010] and the presumably costly advance of knowledge associated with this, which is generally held as a rationale for increased intellectual "mergers" [Laband and Tollison, 2000]. Although the community as a whole makes considerable use of multi-authorships (indicated by the authors per document in Table 2), the frequency of collaboration across different groups remains at a low level.

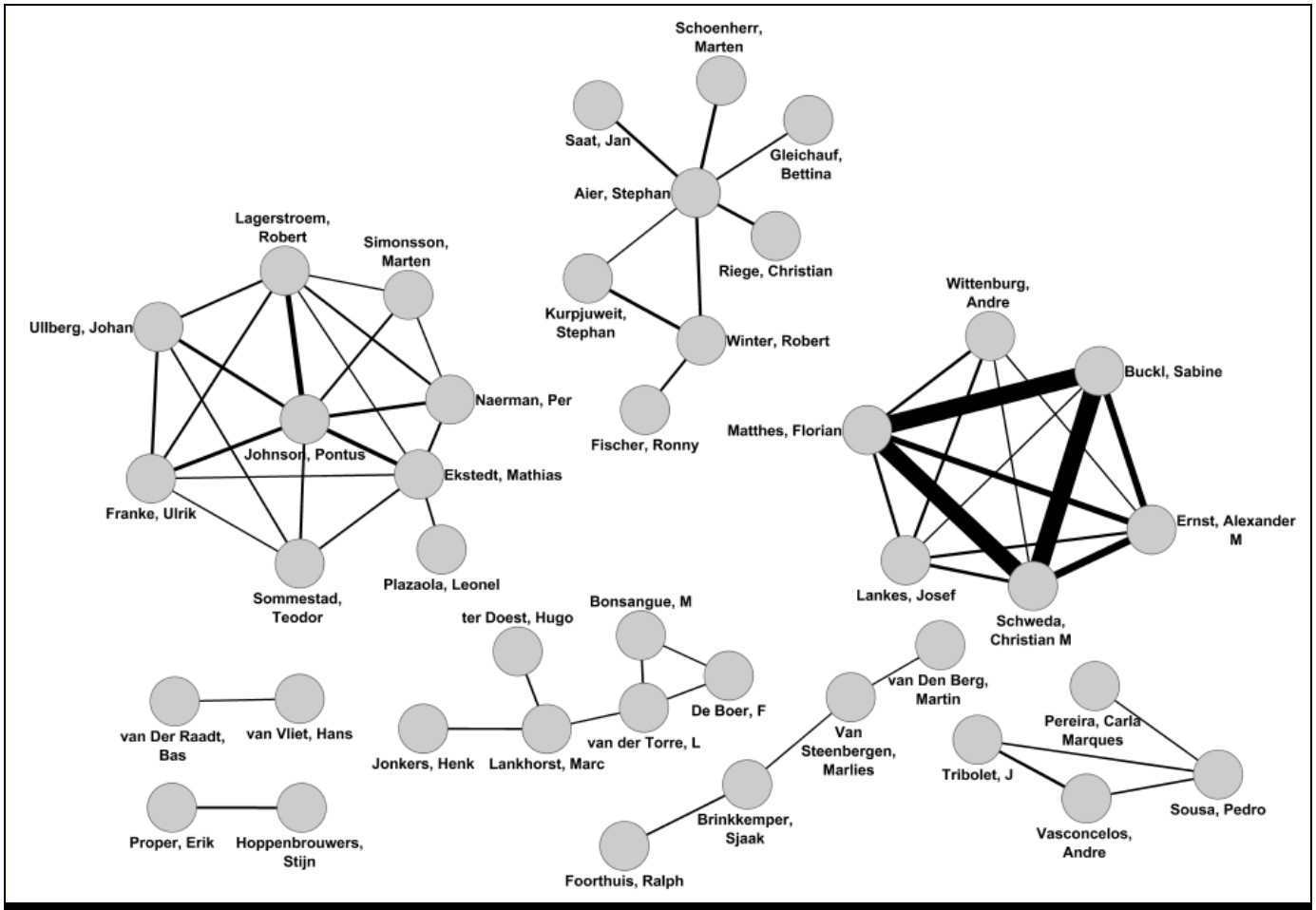

Figure 2. Co-authorship Network (Filtered by Min. Edge Weight of 5 and Min. Degree of 1)

It is interesting that there is quite a difference between the authors with the highest degree centrality scores and those with the highest betweenness centrality scores (see Table 3). All in all, the normalized betweenness centrality scores are quite low, despite the fact that we found a rather modular co-author network, but due to local clusters that are somehow connected. On the one hand, the scores may again indicate moderate "interdisciplinary" [Dolfsma and Leydesdorff, 2010; Leydesdorff, 2007] work within EA research. On the other hand, one may also argue that the network already exhibits some degree of small-world [Uzzi and Spiro, 2005] nature, with considerable local clustering (see above) and moderate global separation (average path length of 2.474)—that is, in terms of author collaboration, EA appears to be one discipline. This supports Schelp and Winter's [2009] thesis of a trend toward an overarching community, despite the appearance of relatively sparse intergroup collaboration.

The most between author is Stephan Aier. All of the main research groups identified find themselves represented among the most between authors (see Table 3). Therefore, each research group seems to have at least one member who (implicitly) plays a leading role in assuring at least some degree of intergroup collaboration.

Ultimately, it is also interesting to note that the co-authorship network has eighty-two isolated nodes, representing authors who have not yet collaboratively created any publication within the EA arena but rather publish only as single authors.

Table 3: Centrality Measures of EA Researchers (Top Ten)

Researcher	Betweenness centrality (norm.)	Researcher	Degree centrality
Aier, Stephan	0.0058	Proper, Erik	44
Buckl, Sabine	0.0045	Hoppenbrouwers, Stijn	37
Johnson, Pontus	0.0038	Buckl, Sabine	36
Schweda, Christian M	0.0037	Johnson, Pontus	34
Proper, Erik	0.0022	Matthes, Florian	33
Winter, Robert	0.0018	Lankhorst, Marc	33
Matthes, Florian	0.0017	Schweda, Christian M.	33
Ekstedt, Mathias	0.0016	Jonkers, Henk	31
Ullberg, Johan	0.0014	Wieringa, Roel	31
Krell, Sascha	0.0014	Iacob, Maria E.	30
		Van der Torre, L.	30
		Bonsangue, M.	30
		De Boer, F.	30

Citation Analysis

With 847 nodes and 4017 edges (including the sample set of documents from EA-related fields), the citation network is of greater density (0.011 for the overall network being interpreted as undirected; 0.019 for the EA network only) but lower modularity (0.323 [0.302]) than the co-authorship network. Likewise, there is less local clustering (average clustering coefficient of 0.185 [0.269]). All in all, this indicates that the citation behavior is different from author collaboration in that it shows a greater crossing of the boundaries of research communities. This overall higher density is also evidenced by the average out-degree (interpreted as the number of times a document is cited) of 4.742 (5.64).

The individual degree centrality scores (see Table 4) underline and pinpoint the central role of frameworks within EA research (note that we count all references to any version of a framework, which might be subject to regular updates, together). In fact, more than 40 percent of the EA publications analyzed refer to TOGAF [The Open Group, 2009] or Zachman [1987]. Remarkably, TOGAF [The Open Group, 2009] has closed the gap and even outranked Zachman [1987] only in recent years; as late as 2005, Zachman [1987] was still far ahead in terms of citations (sixty-eight as opposed to thirty-seven). It is also striking that only three of those publications with at least fifty citations are single-authored.

To shed further light on the relationship between the number of a document's citations and its co-authorship characteristics, we applied simple linear regression, including the number of authors and the year of publication as independent, and the number of citations as the dependent variable. The year of publication is associated with the number of citations in a reasonable direction, that is, the later a document is published, the less it is cited (ß = -0.451). Of particular interest, however, is our finding that the higher the number of a document's authors, the more it is cited (ß = 0.248). Together, the two variables explain 23.5 percent of the variance in the number of citations. In contrast, the incidence of co-authorship (i.e., whether a document is co-authored or single-authored) showed no statistically significant association with the number of citations.

Again, betweenness centralities, though on a rather low level, are somehow different (consider that some frameworks have no references). In terms of their interdisciplinary character, Lankhorst et al. [2005] and Niemann [2006] stand out, with highest betweenness centralities, followed by Dern [2006] and Aier et al. [2008]. It is interesting that one-third of those publications with the highest betweenness centralities are authored by individuals who are isolated within the co-authorship network (see preceding subsection). This is in line with the findings from the above regression analysis that single-authored documents may well obtain a central network position, although, in general, increased multi-authorship promises a greater number of citations.

Within the citation network, 251 nodes (from the 608 nodes representing EA research) are not referred to at all. Nearly 50 percent of these works were published in 2009 and 2010, so it may be too early to expect citations. As for the references to related fields, EA research shows a weak degree of integration (based on the aforementioned sample set of related research). In fact, only 22.53 percent of EA publications cite software/solution architecture works, while 15.79 percent refer to documents assigned to the business engineering/strategic management field.

The enterprise application integration and IT portfolio management fields find even less consideration, with values of 6.09 percent and 1.81 percent, respectively. Eventually, the enterprise modeling/enterprise ontology works, which are generally considered close to EA concerns [Kamogawa and Okada, 2005], are cited by 12.5 percent of our core documents (note that, however, some of our core documents also might be assigned equally to the enterprise modeling field).

Table 4: Centrality Measures of EA Publications (Citation Network)

Reference	Betweenness centrality (norm.) (top twelve)		Reference	Degree centrality (≥ 50)
	Overall network	EA network		
Lankhorst et al. [2005]	0.0119	0.0150	TOGAF [The Open Group, 2009]	246
Niemann [2006]	0.0054	0.0062	Zachman [1987]	244
Dern [2006]	0.0042	0.0054	FEAF [The Chief Information Officers Council, 1999]	125
Aier et al. [2008]	0.0041	0.0052	Lankhorst et al. [2005]	124
Johnson and Ekstedt [2007]	0.0032	0.0035	Sowa and Zachman [1992]	112
Buckl et al. [2008]	0.0031	0.0045	DODAF [Department of Defense U.S., 2009]	83
Engels et al. [2008]	0.0031	0.0042	Spewak and Hill [1993]	83
Schekkerman [2004a]	0.0031	0.0044	Schekkerman [2004a]	77
Langenberg and Wegmann [2004]	0.0031	0.0049	Bass, Clements, and Kazman [2003]	69
Schönherr [2008]	0.0028	0.0045	Ross, Weill, and Robertson [2006]	68
Sebis [2005]		0.0039	GERAM [IFAC-IFIP, 1999]	53
Keller [2007]	0.0024	0.0036	Niemann [2006]	53
McGovern et al. [2003]	0.0024		ZIFA [2001]	51
			Buckl et al. [2008]	50

All in all, this quantitative evaluation of individual research contributions, along with the identification of those of highest relevance, establishes the foundation for a more detailed analysis of the overall research field toward the derivation of structural patterns.

Co-citation Analysis

The co-citation network, representing the same document set as the citation network, not surprisingly also has 847 nodes, but 12988 edges. It is the densest (0.036 [EA network only: 0.053]) and least modular (0.248 [0.249]) of the three networks analyzed. The average clustering coefficient equals 0.412 (0.449). These figures suggest a fairly connected network of several clusters tied closely with one another, as opposed to strictly separate "schools of thought." The publications' centrality scores within the co-citation network mainly verify the above picture in terms of the most prominent and significant works in the EA literature. It provides particular evidence of the dominant role of EA frameworks and of comprehensive works such as Lankhorst et al. [2005], Ross et al. [2006], Schekkerman [2004a], Niemann [2006], Spewak and Hill [1993], Dern [2006], and Keller [2007] (see Table 5).

To gain further insights into the co-citation network, we applied multivariate statistical analysis techniques in the form of factor analysis, which supports the classification of co-citations in research discourses and enables a quantitative appraisal of the relative impact of individual articles within these discourses [Teichert and Shehu, 2010]. We used the raw co-citation matrix introduced above. To remove the scale influences originating from the citation frequencies of two given documents and to measure the similarity of their co-citation profiles, we normalized the raw co-citation matrix in SPSS using Pearson's correlation coefficient (Pearson's r) and thus converted it into a matrix of similarity values [Ahlgren, 2003; Uysal, 2010]. To evaluate its sampling adequacy, we computed the Kaiser-Meyer-Olkin (KMO) measure. Since our data set did not pass this test at first, we successively excluded items with "unacceptable" [Kaiser and Rice, 1974] sampling adequacy (cf. Hair, Black, Babin, Anderson, and Tatham, 2006). The resulting KMO score of 0.786 for the reduced data set, which can be considered nearly "meritorious" [Kaiser and Rice, 1974], proves its general adequacy for factor analysis. Pearson's r's for each pair of the remaining twenty-nine documents were then factor analyzed using the principal component method with Varimax rotation. Based on a scree test (as a means to determine the number of factors to be extracted), we extracted three from four factors with eigenvalues above 1, accounting for 84.84 percent of the matrix's variance. They are listed in Table 6 in order of the variance accounted for, Factor 1 being the highest. The variance extracted by a factor signals the relative breadth of

a discourse in relation to the overall research field. To test the reliability of the factor scale, we also calculated Cronbach's Alpha for each factor. The values listed in Table 6 indicate adequate reliability (cf. Hair et al., 2006).

Table 5: Centrality Measures of EA Publications (Co-citation Network)

Reference	Centralities (top ten)		
	Betweenness centrality (norm.)	Closeness centrality (norm.)	Eigenvector centrality
TOGAF [The Open Group, 2009]	0.0332	0.855	1.0
Zachman [1987]	0.0314	0.802	0.92
Lankhorst et al. [2005]	0.0162	0.748	0.90
Ross et al. [2006]	0.0118	0.699	0.84
Sowa and Zachman [1992]	0.0118	0.723	0.86
FEAF [The Chief Information Officers Council, 1999]	0.0099	0.689	0.76
Schekkerman [2004a]	0.0054	0.660	
DODAF [Department of Defense U.S., 2009]	0.0059	0.651	
Niemann [2006]	0.0052	0.652	
Spewak and Hill [1993]	0.0050		
Dern [2006]		0.659	0.79
Keller [2007]			0.77
Langenberg and Wegmann [2004]			0.76
Johnson, Ekstedt, Silva, and Plazaola [2004]			0.75

It was the documents' factor loadings that primarily allowed us to interpret the factors. This is because the key measures of factor analysis—factor loading (FL) and factor score (FS)—provide complementary information [Teichert and Shehu, 2009, 2010]: factor loadings denote how publications fit into the overall context of one discourse (factor); factor scores indicate, conversely, how much this discourse is influenced by these publications. In other words, the factor score indicates the importance of an article for a research discourse, while the factor loading suggests the extent to which the article can be explained by the factor. We thus assigned documents to the factor, for which they have the highest loading, with a minimun value of 0.5 [Hair et al., 2006]. Against this background, we were able to label the three discourses represented by the factors: EA frameworks, Design and operations of EA management, and EA conception and modeling.

The first factor, which comprises works that can be considered foundational structures of EA content, activities and deliverables (i.e., a set of models, principles, methods, visualizations, etc. [Schekkerman, 2004a]) and thus has a focus on EA frameworks, explains 46.7 percent of the entire variance (after Varimax rotation) and dominates the overall EA research field. This underlines the central position of EA frameworks. These frameworks have very different roots: governmental institutions, standards bodies, academia, and practitioners. Indeed, TOGAF [The Open Group, 2009] has evolved to be the foremost EA framework (its far-reaching influence is also evidenced by its high scores in the other factors), placing first-order attention on a method for architecture development complemented by, for example, descriptions of architectural deliverables, an underlying meta model, generic reference models, and guidelines with respect to architectural roles, responsibilities, and skills. In terms of the factor score, it is followed closely by the Zachman framework [Zachman, 1987], suggesting a two-dimensional scheme of the enterprise along perspectives (e.g., planner, owner, designer) and abstractions (e.g., questions of "what," how," and "where") (note that ZIFA [2001] represents another reference of this framework, but is typically cited together with Zachman [1987]), and the "Federal Enterprise Architecture Framework" (FEAF) [The Chief Information Officers Council, 1999], which primarily permeated U.S. government government agencies (cf. Saha, 2007). The work of Sowa and Zachman [1992] represents an extension of the original Zachman framework [Zachman, 1987] and is thus of similar importance; also Zachman [1997] elaborates on this framework. Likewise, Pereira and Sousa [2004] base their work on Zachman [1987], offering guidance on how to apply this framework. In addition, the U.S. "Department of Defense Architecture Framework" (DODAF) [Department of Defense U.S., 2009], which features a comprehensive set of architecture viewpoints, is present and has exerted influence on this stream, among others on the development of TOGAF [The Open Group, 2009] [Schekkerman, 2004a].

The work of Jonkers et al. [2004] provides an introduction into the ArchiMate modeling language, which has an acknowledged framework character as well (cf. Esswein and Weller, 2008). Another relevant work is that of Bernard [2005], who proposes an EA documentation framework along the three dimensions (thus being labeled EA^3 Cube) architectural levels (ranging from strategic goals and initiatives to networks and infrastructure), segments (one or more lines of business), and artifacts (the documentation products). The GERAM framework [IFAC-IFIP, 1999] can be considered an attempt to provide existing frameworks with a common foundation [Aier et al., 2008] as a kind of meta-framework. Interestingly, there are also works not explicitly labeled or referred to as frameworks that may also need to be considered or are at least implicitly used as such Boar [1998]; Beveridge and Perks [2002]; Ross [2003];

Spewak and Hill [1993]. As already outlined, Schekkerman [2004a] offers a comprehensive overview of existing EA frameworks, which explains why it has found its place within this research stream. All in all, the extremely high factor loadings present (see Table 6) in this stream indicate an especially closed discourse.

Table 6: Factor Analysis of Co-citation Profiles

	Factor 1: EA frameworks		Factor 2: Design & operations of EAM		Factor 3: EA conception & modeling	
Explained Variance	46.7%		23.1%		14.9%	
Reference	FL	FS	FL	FS	FL	FS
TOGAF [The Open Group, 2009]	0.969	1.870	0.060	1.078	0.009	0.655
Zachman [1987]	0.957	1.797	-0.207	0.291	-0.133	0.239
FEAF [The Chief Information Officers Council, 1999]	0.943	1.365	-0.154	0.062	-0.167	-0.294
Sowa and Zachman [1992]	0.910	1.308	-0.117	0.307	-0.350	-0.858
Schekkerman [2004a]	0.897	1.278	0.283	1.012	-0.022	-0.019
Spewak and Hill [1993]	0.887	0.942	-0.402	-1.184	-0.117	-0.130
GERAM [IFAC-IFIP, 1999]	0.882	0.652	-0.314	-0.920	-0.093	-0.250
ZIFA [2001]	0.864	0.568	-0.146	-0.456	-0.341	-1.410
Beveridge and Perks [2002]	0.844	0.379	-0.313	-1.006	-0.332	-1.303
Pereira and Sousa [2004]	0.841	0.469	-0.366	-1.221	-0.026	0.043
DODAF [Department of Defense U.S., 2009]	0.832	0.869	-0.079	-0.033	-0.040	-0.101
Boar [1998]	0.818	0.303	-0.354	-1.155	-0.350	-1.497
Bernard [2005]	0.811	0.344	-0.408	-1.550	0.060	0.217
Zachman [1997]	0.751	0.162	0.015	-0.010	-0.478	-1.805
Jonkers et al. [2004]	0.595	0.188	-0.263	-1.042	0.383	1.040
Ross [2003]	0.520	-0.203	-0.166	-0.807	-0.080	-0.481
Dern [2006]	0.112	0.252	0.926	1.950	-0.086	-0.833
Keller [2007]	-0.158	-0.248	0.914	1.775	0.140	-0.467
Braun and Winter [2005]	-0.004	-0.346	0.802	1.043	0.243	-0.285
Matthes et al. [2008]	-0.549	-1.382	0.739	1.060	0.294	-0.260
Niemann [2006]	-0.335	-0.105	0.702	1.200	0.601	1.393
Buckl et al. [2008]	-0.622	-1.536	0.689	1.078	0.327	0.003
Langenberg and Wegmann [2004]	-0.522	-1.136	0.678	0.731	0.182	-0.451
Aier et al. [2008]	-0.581	-1.644	0.608	0.244	0.402	0.124
Buckl, Ernst, Lankes, Schneider, and Schweda [2007]	-0.699	-2.323	0.598	0.289	0.260	-0.566
Winter and Fischer [2007]	0.035	-0.221	0.246	-0.516	0.917	2.168
Johnson and Ekstedt [2007]	-0.167	-0.491	0.091	-0.846	0.913	2.113
Fischer, Aier, and Winter [2007]	-0.163	-0.421	0.564	0.377	0.654	1.235
Kurpjuweit and Winter [2007]	-0.498	-1.236	0.452	-0.131	0.641	1.178
Cronbach's Alpha	0.978		0.961		0.903	

The second-largest factor, accounting for a variance of 23.1 percent, captures two main themes. With the central position of Dern [2006] and Keller [2007], who offer detailed illustrations of EA processes, it focuses on EA operations, that is, the description of EA management activities. Also Niemann [2006]—another very influential work in this stream—provides a comprehensive guideline on how to execute tasks of the EA function. In addition, the factor comprises works that deal with the design of EA management, thus covering aspects of EA method engineering [Riege and Aier, 2008]. Meta modeling, which provides a conceptual scheme of the enterprise architecture and thus specifies its elements along with their relationships and attributes [Buckl et al., 2007; Kurpjuweit and Winter, 2007; Österle, Winter, Höning, Kurpjuweit, and Osl, 2007; Smith, 2011], seems of particular relevance in this context, since this is at the core of the works of Braun and Winter [2005] and Buckl et al. [2007]. Also, the selection of a tool to implement such a meta model and produce meaningful EA deliverables on this basis is of some relevance here, given the influential position of Matthes et al. [2008], who offer a detailed survey of EA management tools. With the two main themes in mind, we labeled the stream "design & operations of EA management."

The significance of the design theme in the overall discourse can most probably be explained by the considerable risk of failure in establishing an EA function [Buckl, Ernst, Matthes, and Schweda, 2009d; Zink, 2009], for example,

one that does sufficiently address key stakeholder needs. Therefore, the discourse is to some extent dominated by the notion of patterns as "building blocks for the concept of an organization-specific support for EA Management" [Buckl et al., 2007]. This is promoted in particular by the work of Buckl et al. [2008]. Eventually, the stream also contains the review articles of Aier et al. [2008], who elaborate on fundamentals such as EA scope, entities, and analysis techniques, and of Langenberg and Wegmann [2004], who, as stated earlier, evaluate the targets of EA research by 2004. The fact that these reviews are assigned to this factor indicate that this is a field which continually aims to achieve progress, based on consolidated prior research in reviews (cf. Schwarz et al., 2007).

The last factor explains the smallest percentage of variance (14.9 percent) of the three factors extracted. Given their high factor loadings, the works of Winter and Fischer [2007] and Johnson and Ekstedt [2007] are almost perfectly representative for this stream. While Winter and Fischer [2007] suggest a set of essential EA layers and artifacts (architectural objects and their representation in models), Johnson and Ekstedt [2007] elaborate on how to use EA models for rational decision making and the effective contribution to business and information systems goals. With this focus on the fundamental EA structure and models, an appropriate label for this factor seems to be "EA conception & modeling." The fact that modeling is a central theme in this stream is also evidenced by the additional works of Kurpjuweit and Winter [2007] and Fischer et al. [2007] assigned to this factor. These works are concerned with stakeholder-oriented meta model engineering [Kurpjuweit and Winter, 2007] and, having established such a meta model, a federated approach to EA model maintenance [Fischer et al., 2007].

Remarkably, all three factors involve significant works by both academics and practitioners (note that Niemann [2006] also loads considerably on factor 3), supporting the thesis of a tight academic-practical world link in the EA space [Aier et al., 2008] and suggesting that we should not underestimate the impact of individual publications of EA practitioners (as opposed to Schelp and Winter [2009]). Yet, the fact that the initial data set did not pass our test of sampling adequacy, thus indicating high multicollinearity (which would have resulted in a significantly lower variance explained by the extracted factors), and the close relationship between factor 2 and 3 indicated by works loading significantly on both factors support our initial conclusion based on the above network characteristics, that is, the existence of different clusters that exhibit high overlaps between one another. This may adequately explain the in-consistency in terminology, but may also simply reflect the abstract and wide nature of EA that can be interpreted differently and refined accordingly in its own "language communities" [Schelp and Winter, 2009]. Thus, a converging author community does not necessarily reflect the establishment of a common language and mutual understanding, as suggested by Schelp and Winter [2009], even if restricting the analysis to academic publications only.

The results of the factor analysis also provide some counter-intuitive findings regarding the role of some research topics that one might have expected to constitute central factors in the field due to their critical role for EA practice, on the one hand, and their specific characteristics, on the other hand. First, no factors are defined by research on EA planning, although this seems a core concern of EA practitioners [Kappelman et al., 2008], while at the same time being very complex and demanding (cf. Schmidt and Buxmann, 2011). In recent times, some researchers (e.g., Aier et al., 2009; Saat, Aier, and Gleichauf, 2009; Saat, 2010) have apparently shifted their attention to that topic, but this has not yet developed into a central research stream.

Second, from a systemic point of view (cf. Buckl, Matthes, and Schweda, 2009f), there is no factor concentrating on the integration of EA management with other management functions, which, however, seems crucial for efficiently maintaining the completeness, correctness, and topicality of EA content. According to Buckl et al. [2009b], this is indeed another concern of major importance for EA practitioners. Although specific works present in our analysis are concerned with model maintenance (e.g., Fischer et al., 2007), a major stream is again not yet visible.

Third, specific application scenarios of EA management have not emerged as core streams. For example, mergers and acquisitions [Mehta and Hirschheim, 2004] and outsourcing [Lacity, Khan, Yan, and Willcocks, 2010], both of which represent distinct situations in which EA management can be applied [Winter, Bucher, Fischer, and Kurpjuweit, 2007], have long been established as particular instruments of strategic management by many enterprises. Few works, though, explore the role of EA management in M&A (e.g., Freitag, Matthes, and Schulz, 2010; Mo and Nemes, 2009); the same applies to its role in outsourcing and to its application in the context of the increasingly used [Janssen and Joha, 2004; Schulz, Hochstein, Uebernickel, and Brenner, 2009] "internal" outsourcing option of a shared service center (e.g., Arnold, Op't Land, and Dietz, 2005; Op't Land, 2008; Versteeg and Bouwman, 2006). This is despite that in practice this scenario may require a very specific and complex EA model, that is, one which reflects greater service orientation and can be applied recursively to different parties in the role of both service provider and consumer.

To augment the above analysis, we also examined our data set using the ALSCAL multidimensional scaling routine of SPSS. ALSCAL illustrates proximities as distances on a map and allows the visualization of the correspondence between different documents [Uysal, 2010]. That is, the more closely two documents are represented on the map,

the more similarities they share in terms of their co-citation patterns [McCain, Verner, Hislop, Evanco, and Cole, 2005]. The resulting Stress I value of 0.10 coupled with the RSQ value of 0.95 represent a fairly good approximation of the underlying data [McCain, 1990].

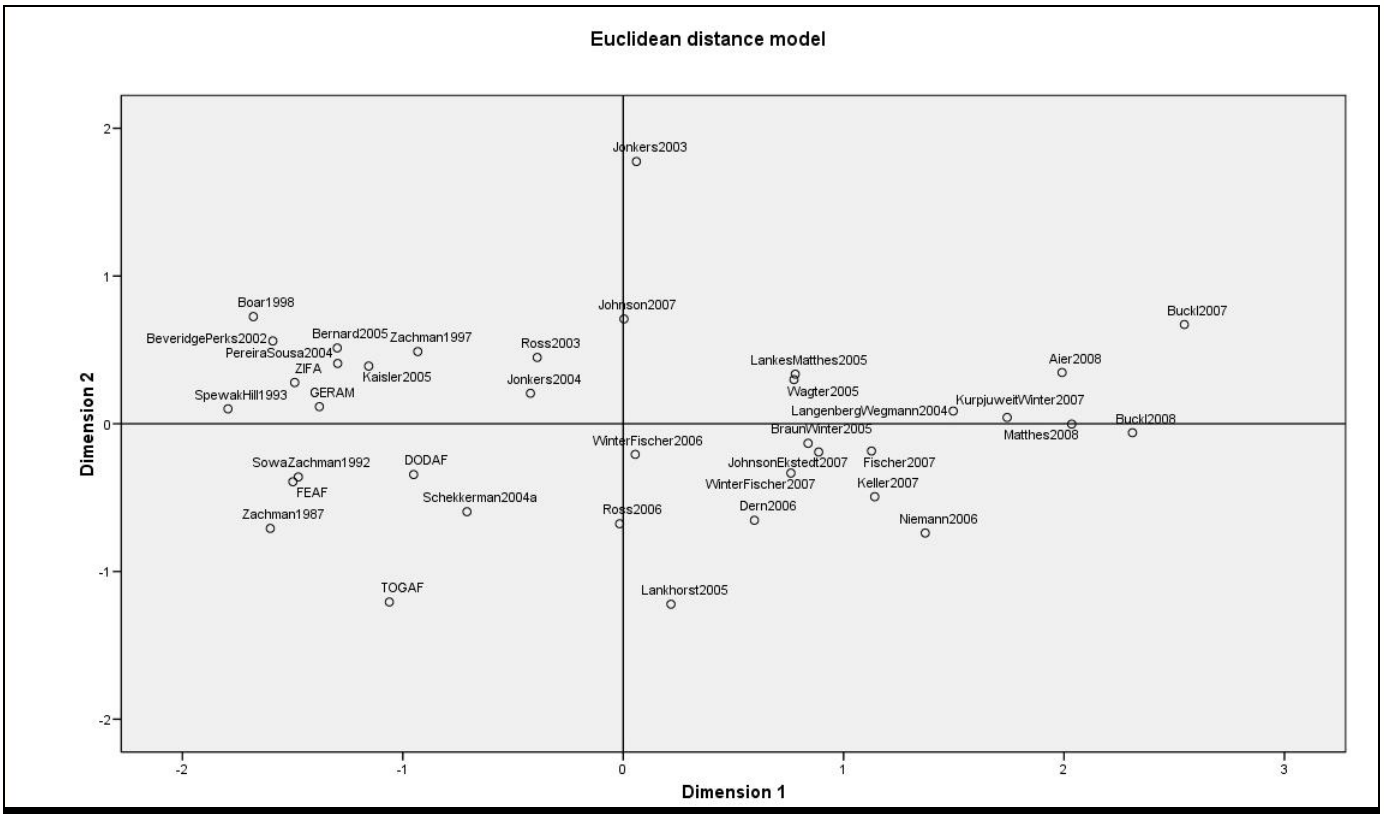

Figure 3. Multidimensional Scaling Map of Document Co-citation Profiles

From an impressionistic point of view, moving from left to right along the X-axis (dimension 1) of the resulting map seems to describe the continuum from theoretical foundations to more practical issues and patterns of EA management, while the Y-axis mirrors a certain gradation of focus on specific subjects (i.e., from a wide scope at the bottom end to a rather narrow focus (e.g., Jonkers et al. [2003] examining a specific modeling language) at the top end). The co-citation map (see Figure 3) clearly reflects the three main research streams identified, with the "EA frameworks" populating the left-hand side and the documents belonging to "Design & operations of EA management" and "EA conception & modeling" situated on the right-hand side. As for the latter discourses, the rather dense placement of the corresponding documents evidence close mutual ties, that is, "Design & operations of EA management" and "EA conception & modeling" understandably share common themes, since developing, instantiating, and maintaining an EA model is an integral part of establishing and running an EA practice (also see the factor analysis results, with loadings of Niemann [2006] and Fischer et al. [2007] being above 0.5 for both discourses). For all of the discourses discovered, it is worth noting that these are not influenced predominantly by a single research group but can take advantage of balanced contributions.

Content Analysis

To move the state-of-the-art analysis along and gain more insights into particular aspects of the different streams (e.g., which architectural layers and method building blocks are discussed most), we conducted a detailed content analysis of the 608 core documents. We applied a classification scheme based on the dimensions EA layers, EA methodology, EA management tasks/processes, and EA lifecycle phases, defining for each the corresponding characteristics to be used for coding the documents (cf. Gable, 2010). Accordingly, we classified the EA publications using a multiple item coding system (cf. Langenberg and Wegmann, 2004) per dimension; for example, each publication was assigned to one or several EA layers addressed (except for works, in which a certain focus and corresponding contributions could not be identified, such as in general literature reviews). The comparative analysis [Neuendorf, 2002] enabled by this complemented the applied bibliometric methods and shed light on whether literature to date has revolved around very specific EA subjects.

EA layers represent conceptual domains [Jonkers et al., 2004] of enterprise architecture and make up the basic structure of an enterprise architecture model [Matthes et al., 2008] by capturing related entities [Janssen 2009;

Winter and Fischer, 2006]. The most prominent of these layers are business architecture, application architecture, information architecture, and technical architecture [Janssen, 2009; Matthes et al., 2008; Platt, 2002; The Open Group, 2009]. Beyond that, the "cross-cutting aspects" [Buckl, Matthes, and Schweda, 2010] transition (e.g., projects) and standards constitute separate domains. Knowing that it is common practice to differentiate enterprise architecture into various layers, we surveyed our EA source documents with respect to the layer(s) with which they deal. This resulted in 410 documents for which we could identify at least one EA layer covered. Application architecture is represented most often by some 83 percent of these publications, closely followed by business architecture at 78 percent (although some publications may not discuss business architecture management per se, but rather aspects of it in the context of application landscaping). In contrast, technical architecture (53 percent) and information architecture (45 percent) garner less attention, and transition (13 percent) and standards (10 percent) receive only minor attention (see Figure 4).

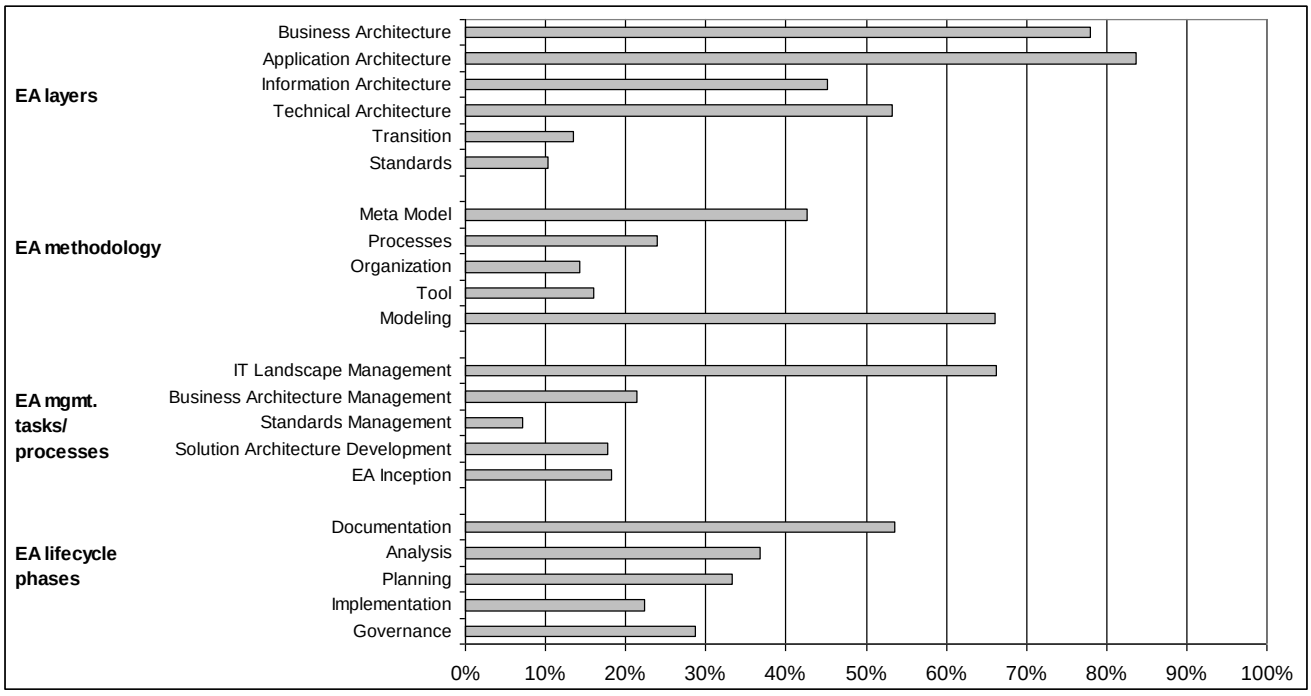

Figure 4. Results of Content Analysis

Business architecture can be divided further into business strategy and business organization [Winter and Fischer, 2006]. Potentially, there is even a third sub-layer—the business model. Capturing elements such as value proposition, customer segments, distribution channels, and revenue model, the business model provides a blueprint of the strategy as well as a link between abstract strategy and concrete organization [Hedman and Kalling, 2003; Osterwalder and Pigneur 2002, 2003; Osterwalder, Pigneur, and Tucci, 2005]. It is interesting that of the 320 publications that deal with business architecture, nearly 95 percent tackle the business organization, while only 41 percent are concerned with business strategy. The business model finds even less consideration (32 percent). The discourse on business organization [Schönherr, 2008] concentrates far more on business processes (93 percent) than on organizational structures (60 percent).

Defining the "how" of EA management [Bernard, 2005], EA methodology—the second coding dimension—essentially comprises the following core method elements of EA management: EA meta model (the conceptual scheme of EA content), processes, organization (e.g., roles, responsibilities, committees), tool, and modeling (the representation of EA content) [Bernard, 2005; Johnson, Johannson, Sommestad, and Ullberg, 2008; Leist and Zellner, 2006, 2008; Niemann, 2008; Simon, 2009b]. Accordingly, we analyzed our set of EA publications, from which 342 were classifiable. We concluded that modeling (66 percent) and the EA meta model (43 percent) far outrank processes (24 percent), tool (16 percent), and organization (14 percent) in terms of attention in the literature.

EA management tasks/processes was the third dimension analyzed; its main constituents are IT landscape management, business architecture management, standards management, solution architecture development, and EA inception (the establishment and advancement of EA methods) [Andresen, Gronau, and Schmid, 2005; Hanschke, 2010; Hafner and Winter, 2008; Hirvonen, Pulkkinen, and Valtonen, 2007; Kurpjuweit and Winter 2007; Simon, 2009a; Slot, Dedene, and Maes, 2009; Smith, 2011; The Open Group, 2009]. The figures based on the 281

classifiable documents accordingly reveal that IT landscape management (66 percent) occupies the center stage of research, far ahead of business architecture management (21 percent), solution architecture development, and EA inception (both 18 percent). Standards management (7 percent) goes rather unconsidered. Between 2003 and 2010, as more on EA is published in general, we even note an increase in the focus of the literature on IT landscape management.

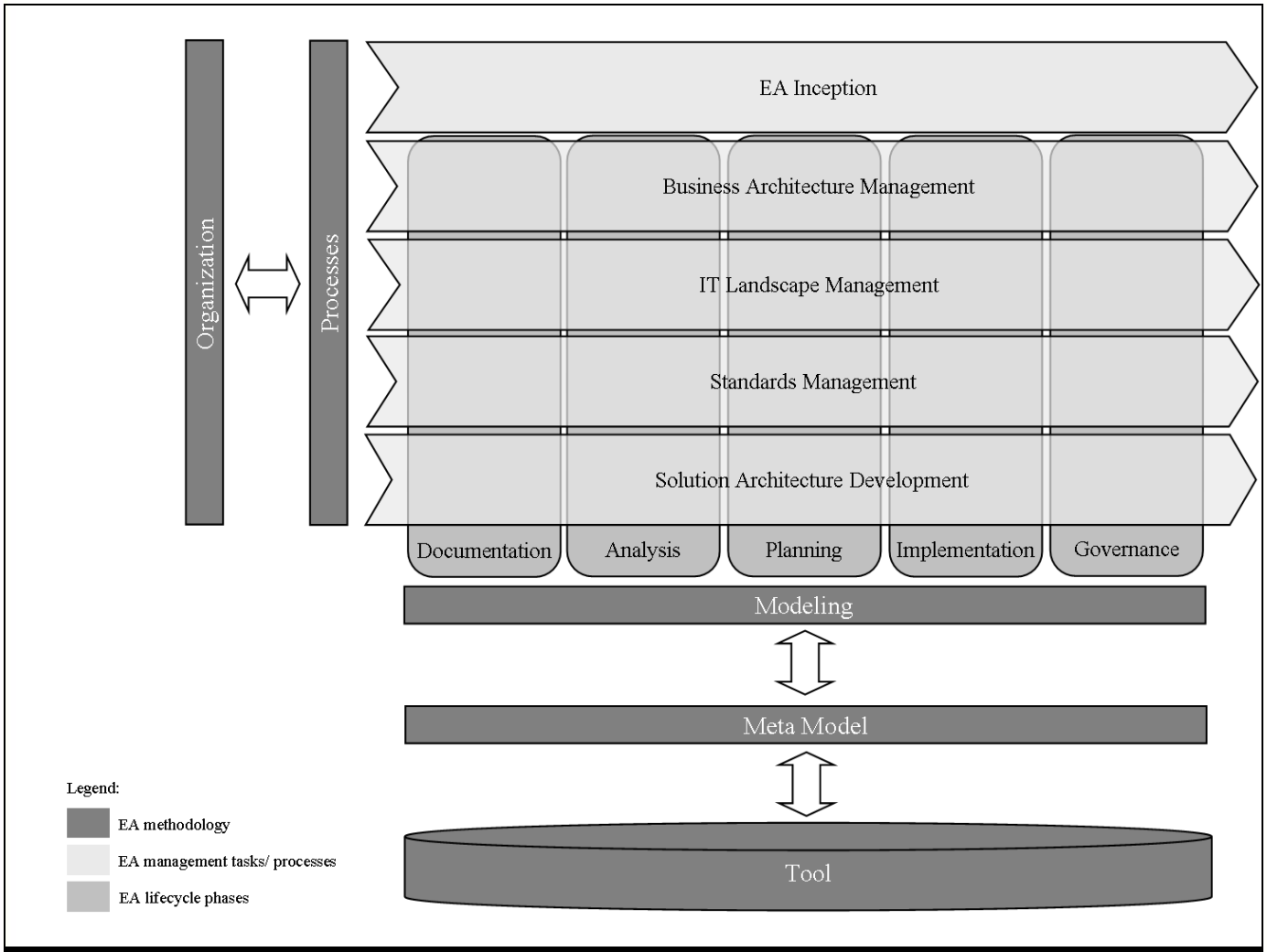

Figure 5. Dimensions of Content Analysis (Except EA Layers)

In addition to the aforementioned tasks/processes, the literature also deals with the phases of documentation, analysis, planning, implementation, and governance. These terms are often misinterpreted. While some view them as together constituting the one and only EA management process (e.g., Buckl, Ernst, Matthes, and Schweda, 2009e), we consider them phases of the EA lifecycle through which elements and artifacts of enterprise architecture are driven [Niemann, 2006, 2008] and which can, therefore, be interpreted as having an orthogonal and cross-cutting character with respect to the different EA management processes (see Figure 5). The classification of our source documents (327 classifiable) reveals that literature concentrates primarily on documentation (54 percent), whereas the phases of analysis (37 percent), planning (33 percent), implementation (22 percent), and governance (28 percent) have not permeated literature to the same degree. Information gathering, considered an essential part of documentation [Simon, Fischbach, and Schoder, 2010], remains a minor research topic (10 percent of this discourse).

Figure 5 brings the dimensions of our content analysis into relation with one another (for the sake of simplicity, we did not include the EA layers), displaying that the EA lifecycle phases basically apply to each EA process (except EA inception due to its preliminary character). In other words, the EA processes are permeated equally by the EA lifecycle phases, in each of which models of different abstraction and specificity are created and used. These models are based on a common meta model, which is in turn implemented in an EA tool that allows populating this meta model and thus generating specific architectural models. Finally, the EA processes, in which modeling occurs,

are subject to a certain involvement of roles and boards of the EA organization, thus completing the EA method elements we investigated in literature and found to be dealt with to a significantly different extent.

Table 7: Findings for Research Questions 1, 2, and 3

	Research question	Main findings
1	How do scholars in the field collaborate via co-authorships (in comparison to other fields) and what impact does this have on the diffusion of their contributions?	• The co-authorship network is quite clustered and there is moderate collaborative work across different research groups in terms of its frequency. • Still, there is some degree of a small-world nature, since global separation is also only moderate. • Documents are cited more often the more authors they have, while the sole incidence of co-authorship has no statistically significant association with the number of citations.
2	What are the main research streams in the field, how are they interlinked and what are the major works to be assigned to these streams?	• There a three major research streams (according to the co-citation patterns): "EA frameworks," "Design & operations of EA management," and "EA conception & modeling" (see Table 6 for the assigned documents). • EA frameworks and other comprehensive works, including from individual practitioners, play a central role within the research field. • No major streams are defined by highly relevant topics like architectural planning, the integration of EA management with other practices, and specific application scenarios of EA management (e.g., M&A, outsourcing). • There is some gap between theoretical foundations and practical issues in EA research (as per the multidimensional scaling map and the closed character of the EA frameworks stream as suggested by the factor analysis results). • According to the citation patterns, the integration with related research fields seems rather moderate.
3	How does the focus of work spread within specific dimensions of EA research content (e.g., architectural layers)?	• EA layers: Application architecture is represented most often in EA research. At the business architecture layer, research is concerned more with the business organization than with the business strategy and model. • EA methodology: EA research focuses on (meta) modeling, while EA processes and organization receive less attention. • EA management tasks: IT landscape management occupies the center stage of research, far ahead of business architecure management, solution architecture development, and standards management, for example. • EA lifecycle phases: The literature concentrates primarily on documentation, whereas the other lifecycle phases find less consideration.

With the individual document profiles created through the above classification, we also obtained a reasonable justification for the identified central position of works such as Dern [2006], Keller [2007], Lankhorst et al. [2005], and Niemann [2006], since these profiles substantiated their comprehensive character indicated. It is also interesting to look into the focus of the main research groups mapped above. In general, this reflects the overall picture depicted above, but there are some fine differences. The TU Munich research group appears to concentrate on IT landscape management, particularly on documentation, while solution architecture development is not considered to be a subject of EA management [Buckl et al., 2009e]. Similarly, the KTH Stockholm research group addresses mostly IT landscape management, but apparently puts greater emphasis on the analysis and planning lifecycle phases. Only the University of St. Gallen research group takes business architecture management and corresponding analysis into greater account, attaching greater importance to the business strategy and business model part of business architecture.

As for the main research streams identified through our factor analysis, the content analysis supports the central role of EA modeling and also indicates clearly that the theme of EA management design as captured by the second factor thus far revolves around meta modeling. EA organization remains on the sideline, particularly in the most significant works. The theme of the operations of EA management is geared heavily toward IT landscape management, especially the documentation phase, but there is little research on standards management. This is also reflected in what we called "EA conception & modeling," with the layers of standards and transition being of minor relevance within the discourse.

Table 7 summarizes the findings for our first three research questions, which we have gained through the above analyses. In the following section, we build on these findings and, complemented in particular by empirical

observations documented in the literature (cf. Webster and Watson, 2002), discuss future possibilities in EA research (corresponding to our fourth research question).

IV. DISCUSSION: A PROPOSED AGENDA FOR FUTURE EA RESEARCH

With an aggregated interpretation of the above findings on the terrain of enterprise architecture, there are a number of insightful conclusions that can be drawn with respect to research history, current state, and, most important, reasonable future research directions, for which we make use of different reasoning coming from theoretical explanations, past empirical findings, and practice or experience as suggested by Webster and Watson [2002] to highlight the differences between "what we know and what we need to know."

Comparing the distribution of publications over time, it becomes evident that enterprise architecture (labeled as such) is still a relatively young but not as immature a research discipline as (identified by Langenberg and Wegmann [2004]) several years ago, and that the Internet hype, involving priorities other than enterprise architecting, may have indeed partially impeded faster adoption (as assumed by Langenberg and Wegmann [2004]) until the dot-com bubble burst in 2000. It can now be considered a very lively research field, in which academic efforts in particular have increased significantly since 2003 (see Figure 1). It is interesting that this is driven primarily by European researchers, and as more is published, the more EA research centers in Europe. This may be traced back to the findings of Schekkerman [2004b]. They indicate that EA management was already more embedded in U.S. companies at that time, which may have led to less interest in research by the time these studies proliferated. In line with Acedo et al. [2006], who in the field of management identified a smaller tendency toward joint publications in Europe than in the United States, the fact that in the past years research activities concentrated on Europe may in turn have at least partially led to the present fragmentation of the co-authorship network.

As all our methods applied have shown, a significant part of the development in the EA arena can be attributed to the frameworks. On the one hand, this is due to their influential role according to the citation patterns uncovered by our analysis. Most notably, this is the case for TOGAF [The Open Group, 2009], for which we found consistently high values in our factor analysis. On the other hand, frameworks themselves represent results of research activities to some extent (e.g., ArchiMate), integrating, summarizing, and conceptualizing knowledge [Schwarz et al., 2007], and thus constituting an advance in the research field itself. In addition to the designated frameworks, there are other comprehensive works (especially books) by both academics and practitioners that our analysis revealed as important contributions. Further enhancements of these works in the future, adopting new trends and developments, appear to remain valuable, since with the variety of considered EA facets (as identified by our content analysis) they evidently come close to providing a coherent picture of the overall EA concept.

At the same time, EA terminology must still become more consistent to assure the integratability of different approaches, especially that of designated frameworks and "customized" architectural methods. Given the huge initial efforts associated with the implementation and use of a framework [Röwekamp, 2010], which many practitioners consider to be too theoretical [Buckl et al., 2009b], this integration constitutes an apparently fruitful research avenue (although this is not meant to say that research should further increase its focus on frameworks). Specific attempts to achieve progress have already been made (e.g., Buckl, Ernst, Matthes, Ramacher, and Schweda, 2009c, who complement TOGAF with viewpoints patterns); however, further efforts should follow to continually close the gap between theoretical foundations and EA practice uncovered by our co-citation analysis (where we found a relatively closed stream of EA frameworks placed apart considerably from more practical issues of EA management in the multidimensional scaling map, and a certain desire of progress in research on operating issues of EA management indicated by the review articles assigned to this factor). Further, such efforts should concentrate on achieving a defragmentation of the research streams beyond the "EA frameworks," "Design & operations of EA management," "EA conception & modeling" (i.e., those streams that have not been extracted in the factor analysis) and a consolidation into dedicated focuses on, for example, architectural planning, the integration of EA management into the enterprise, and the application of EA management in specific scenarios such as M&A and outsourcing (cf. Leimeister, Leimeister, Fähling, and Krcmar, 2008) to account for the relevance in practice (see discussion above).

This appears to be one of the main challenges for the EA research community. Therefore, collaboration (beyond potential interactions at conferences or in program committees) across different research groups—especially intercontinental and cross-academic—may need to improve. For a small-world network to become a reality, research groups may consider establishing specific representatives who regularly participate in the research projects of other groups and thus facilitate identifying the most relevant research questions, the accelerated transfer of new ideas, and the gradual achievement of a common language. In a small-world network, clusters can be linked by persons who are members of multiple clusters, making it possible for even large communities comprising many separate clusters to be connected and cohesive. In particular, this collaboration should entail an increased number of, preferably internationally, co-authored publications, which have been shown to be more likely to be cited on average and to appear in high impact journals [Acedo et al., 2006; Glänzel and Schubert, 2004], both of which facilitate their

diffusion. This is also supported by the findings of our study, which indicate that this applies in a similar way to EA research, that is, the number of a publication's authors shows a positive impact on the number of citations it receives.

Of similar importance is a closer integration with related research fields, to account for the fact that EA management is not likely to work effectively if regarded as a stand-alone function and thus collaborates closely with other management functions in practice (as evidenced by Winter et al. [2010]), and to enable a mutual learning process and methodological substantiation (e.g., with portfolio assessment techniques). This could also be incorporated in university education, where EA management is still insufficiently represented [Buckl, Dierl, Matthes, Schulz, and Schweda, 2009a; Schmidt 2009] but where the foundation for a common understanding and effective communication with both business and IT stakeholders can be set.

Furthermore, the analysis reveals a range of specific topics that—in light of the significant role that research may play in progressing a field—deserve more in-depth investigation, for example, the exploration of EA management constituents other than IT landscape management. This is particularly the case for standards management and solution architecture development. With relatively scarce research on standards management, there is a unique opportunity for academics to substantiate a field that is an integral part of the most important success determinant of an EA function (according to Schmidt and Buxmann [2011])—architecture governance. In fact, there is strong evidence for both the significance of using EA standards in effectively managing IT resources [Boh and Yellin, 2006] and the positive impact of IT standardization on IT agility [Tiwana and Konsynski, 2010]. Likewise, EA-based solution architecture activities have been shown to be of considerable business value [Slot et al., 2009], which is also fostered by other research currently in progress by ourselves, indicating that solution architecture development is considered a primary field of relevance for an EA management function by practitioners. However, as the number of citations for software architecture works indicates, there is a low degree of integration between research on strategic and operational architecture management, both key aspects of EA management [Niemann, 2008]. Given the "ivory tower" syndrome and the lack of integration with operational activities from which many EA practices suffer, which may fundamentally jeopardize their success [van der Raadt, Schouten, and van Vliet, 2008], further research is required to progress toward achieving an integrated view of the discipline as a whole.

This also involves developing a more comprehensive approach to business architecture management, research into which most often centers on the implementation level, that is, the business organization. Conversely, both business strategy and business model (the latter having surged into the management vocabulary over the past years [Shafer, Smith, and Linder, 2005]), receive only minor attention. This is evidenced by relatively few references to business engineering works. With this research focus, the alignment of business and IT [Goeken, Johannsen, and Pfeiffer, 2008; Wieringa, Blanken, Fokkinga, and Grefen, 2003], which is one of the main benefits associated with EA management [Kappelman et al., 2008; Valorinta, 2011], is tackled only on an operational level. Further, research misses the opportunity to leverage the discipline's business design capability [Aitken, 2009] and the potential of the business model concept [Osterwalder et al., 2005; Österle et al., 2007] to facilitate the practical translation of strategy into business execution [Parker, 2009], contribute to a shared understanding between business and IT, and support IT portfolio management [Osterwalder et al, 2005]. This potential also seems widely acknowledged by many IT professionals, whose perception is that business architecture is implemented only to a small extent of what they really need [Leganza, 2010]. This is also in line with the findings of Franke, Ekstedt, Lagerström, Saat, and Winter [2010], who through a survey among European practitioners uncovered that currently EA methods are perceived to support business-IT-alignment only to a moderate extent, although this is considered a highly relevant issue in companies. In a recent study, Aier, Gleichauf, and Winter [2011] even showed that a balanced approach to EA management with respect to business and IT goals promises by far the greatest success. With a shift in their agenda, researchers could make a contribution that allows the EA discipline to increase its business focus. This is again where a closer collaboration is likely to be critical to allowing the integration of different knowledge and to operating successfully within the wide continuum EA management offers, for example, from strategy to execution, from business to technology, and from abstraction to detail. This collaboration should also include researchers from the enterprise modeling/enterprise ontology field, acknowledging that the enterprise ontology represents the highest-level constructional model of the enterprise [Dietz and Hoogervorst, 2008] and that the basic idea of enterprise modeling is to offer different views on the enterprise that allow for various levels of abstraction and can be integrated with one another [Frank, 2002].

Whether it is business architecture management, IT landscape management, or any other constituent of EA management, the results of our analysis, compared to findings from the literature, indicate that future research should put greater emphasis on activities other than documentation to prove that this is more than a paper-based science and to meet the expectations of many practitioners that enterprise architecture can be a decision-making tool [Kappelman et al., 2008; Schekkerman, 2004b]. Hence, another essential research step may be a deeper examination of the lifecycle phases of analysis (for which Aier et al. [2008] identified a need for greater methodical

support, for example) and planning (in line with our above conclusions derived from the results of our co-citation analysis). Among others, this also involves integration with research on IT portfolio management, which thus far hardly exists, to tap the full synergy potential (as depicted in Simon [2009b] and Simon et al. [2010]). Moreover, it implies directing greater focus on the temporality aspects [Aier et al., 2009; Buckl et al., 2009e; Saat, 2010; Saat et al., 2009] of EA management (cf. Aier et al., 2008), which relate to the transition layer (e.g., projects) of enterprise architecture and complex scenario planning, all of which are likely to increase in significance in future EA practice [Wolff, 2011].

Not to be forgotten, there seems to be a need to substantiate the moderately discussed lifecycle phase of governance. This is because it is a multi-faceted phase that captures a number of activities critical to success of the EA function, such as conformity and compliance checks, transformation monitoring, maturity assessments [Becker, Niehaves, Poeppelbuss, and Simons, 2010], and performance measurement [Lucke et al., 2010]. To quote Weill and Vitale [2004], "[T]he difference between management and governance is like the difference between a soccer team running harder and practicing longer and the team stepping back to analyze its composition and game strategy." The measurement of results thus is of particular importance, since this provides the basis for justifying and selling the value of an EA function in the long run—a challenge that EA practitioners increasingly face today [Schelp and Stutz, 2007].

The shift in focus within both EA management tasks and lifecycle phases may be reflected adequately in further explorations of the underlying EA methodology. Analysis and planning are more challenging than documentation and pose higher requirements to meta modeling, and this is where research can provide particular assistance. In general, however, the modeling aspects may take a back seat in the discourse to EA processes and organization, which are of great practical relevance (cf. Lucke et al., 2010; Schmidt, 2009) but only thus far rudimentarily substantiated thus far (cf. Strano and Rehmani, 2007). To close this discussion, we can conclude that the discipline of enterprise architecture has already been subject to impressive development, but there is still some way to go.

V. SUMMARY

Essentially, our study shows a growing interest in EA research. Nowhere does this come through more clearly than in the increasing number of publications since 2003, with European researchers being the major drivers. We were able to identify the most active research groups, which may be on their way to becoming a small world but not yet a common-language community. Further, we provide quantitative evidence of the significance of individual publications within the overall research field. Among other things, this supports the central role of EA frameworks and other comprehensive works, including from individual practitioners.

We also derived three main structural patterns: EA frameworks, design and operations of EA management, and EA conception & modeling. From our additional qualitative analysis with respect to specific subjects of research comes a whole range of insights—for example, the research focus on (meta) modeling and IT landscape management. In contrast, the suggested terrain for future research involves greater emphasis on business architecture management (at the strategic level), standards management, the integration with operational architecture management, and, in general, EA lifecycle phases beyond documentation. A shift of focus to EA processes and organization may provide the necessary basis and also facilitate giving more pragmatic advice, needed to attract practitioners.

In consequence, given the answers we provided for our main research questions, the contribution of our study is manifold. First, to our knowledge, it is the first to analyze collaboration in EA research and its impact on document citation. Compared to other fields, we have found a quite clustered network, and we have good evidence that documents are cited more often the more authors they have. This led us to the suggestion of using a higher frequency and level of (preferably international) co-authorship to complete a research document and establishing "research ambassadors" as representatives to fellow research groups in order to promote scientific exchange and make further progress in the field.

Second, our study provides a unique overview of the intellectual structure of the research field, that is, its main research streams according to prevalent co-citation patterns and the most influential works within these streams. On the one hand, this allows researchers to position themselves and their work within the overall research field; senior researchers in particular may benefit from this study's appreciation of their work. On the other hand, for both academics and practitioners, especially those new to this area, the description of the main streams and the most central work (e.g., designated EA frameworks) that has emerged from co-citation analysis offers orientation and guidance and hence facilitates entry into the research field (although there may be further important topics, e.g., EA principles, not captured by our analysis of the three largest factors according to the co-citation patterns). This study's results are thus also relevant from a practical point of view. Although practitioners typically do not study the scientific literature in detail, they may well work closely with academics. This also applies to the EA field, as indicated by central works present in our study that were developed in close collaboration between academia and practice (e.g.,

Buckl et al., 2008; Matthes et al., 2008). Our study may help practitioners identify scholars with whom they may find it interesting to work, and, in addition, central publications of other practitioners whose contributions we have found to be significant and that practitioners may want to read.

Third, the content analysis, which we used in addition to the bibliometric methods, provides further insights into the body of literature in terms of the specific focus adopted by individual works. The result is a comprehensive profile of the research field that contributes significantly to an understanding of the current self-conception of the discipline. Junior scholars who examine these results will gain a better understanding of the research tradition and, combined with the insights obtained through the bibliometric analysis, of the clusters of both authors and works that have predominantly influenced the field. The classification framework itself used for content analysis comes as another valuable result of our work, since this structure of the topic and the way in which the dimensions are brought in relation to one another help clarify previously confused constructs of EA management and thus facilitate communication and the achievement of a common understanding.

Eventually, the results of both bibliometric and content analysis in this study, set in contrast with issues in EA practice evidenced by the literature (as per our discussion in the penultimate section of this article), indicate areas where specific research is needed and thus open up myriad research possibilities. While the existing body of EA research has become meritorious, the field continues to face significant challenges and is likely to remain a rich field of inquiry. Therefore, the purpose of this study was not to criticize prior work; rather, it identifies and emphasizes the need for future academic work and alerts scholars to fruitful lines of research (which we do not claim to be exhaustive), given certain scientifically underexplored yet promising and challenging themes from a practical point of view. These lines involve not only a more balanced examination of certain architectural layers, method elements, EA management tasks, and lifecycle phases, but also an increased use of applied research to overcome potential gaps between theoretical foundations and the application of EA management. Indeed, it is remarkable that, in contrast to other fields (e.g., Culnan, 1986; Teichert and Shehu, 2010), our study does not identify any larger application-oriented research streams, such as the use of EA management in M&A and outsourcing. The same applies to highly practical challenges like architectural planning and the integration of EA management into the enterprise, which have similarly gained little attention so far, but where the further development of tool support constitutes a particularly interesting field of collaboration between research and practice. As for the dominant stream of EA frameworks, our study suggests putting greater emphasis on the practical use of these frameworks in the future. Also, our results may be valuable for the frameworks themselves, as they point to specific aspects that may need to be considered in further advancements of these works.

Our results have value despite the limitations of this study. First, there is no precise definition of what constitutes EA research, which is due in particular to the abstract and broad character of the concept as whole and other, more "modern" terms used as substitutes for "enterprise architecture." Although we made every effort to draw a complete picture, there may still be some documents we have not included. In particular, some of the most recent papers may not have been adequately considered, given the retrospective nature of the bibliometric methods applied. The most recent research may not yet be published. Given the inherent time lag, a greater representation in leading journals could take several years. Further, there is no differentiation between whether an article is cited positively or negatively, since the citations are neither valued nor totaled according to the number of occurrences per paper. As indicated, there could be quite different motives behind the citing behavior of authors. Biased citing and both inadequate self-citation and reference of secondary sources may be the consequence [MacRoberts and MacRoberts, 1996]. In addition to the context of citation, journal prestige [Chua, Cao, Cousins, and Straub, 2002] and the importance of the citing documents [Ding, Yan, Frazho, and Caverlee, 2009] may be other factors to use when evaluating individual publications. A final limitation comes from the fact that we excluded from our analysis various sources lacking references, such as marketing material and white papers from EA consultancies and tool vendors. In doing so, we may have missed documents that provide significant guidance to EA practitioners in their everyday work and thus make an essential contribution to their overall body of knowledge; in fact, there may be further documents of high practical significance that include no references.

Given these limitations, our study could be extended in various ways. First, sentiment analysis may represent a way to value citations and thus account for the quality of a reference. Second, consideration of journal prestige measures could allow the examination of individual research contributions to be taken to an even more accurate level. Further, bibliographical coupling could be used as an additional instrument to complement co-citation analysis, not only to explore established research streams or tendencies but also those emerging most recently. With a deeper regional differentiation of contributions, it might also be possible to gain greater insights into the geographic distributions of overall research streams and the diffusion of specific concepts. In that context, it might be reasonable to collect further publications in languages other than English and German. For the co-authorship network, future research may also need to consider dynamic analysis, since one might argue that nodes and edges disappear over time when collaboration ends or when an actor leaves the research field. The classification approach used for content

analysis could potentially be bolstered in the future by adding further dimensions and by looking into the quality of contribution. To mirror the results to further developments and trends in practice, it also seems promising to conduct an additional survey among practitioners.

An essential future step would be to run the analysis again in a few years to review the further evolution of the research field and, specifically, any progress made in the future research topics we recommend. Enterprise architecture (as labeled as such) is still a relatively young discipline, and while a strong framework orientation has been characteristic of recent years, newer streams may achieve similar importance in the near future. In this respect, another interesting opportunity for future research is to bring practitioner documents lacking references into the focus of analysis and explore whether patterns similar to those summarized in Figure 4 emerge, that is, whether the overall body of practitioner literature, similar to our literature set dominated by scientific sources, also shows a strong focus on (among others) conceptual frameworks and modeling rather than on, for example, the use of EA management in M&A and outsourcing. While practitioners may find it interesting to see that the analysis in its current form already reflects some of their major issues, they may show even more interest in an extended analysis that considers further documents that belong to their practical frame of reference. Such an analysis might also include additional sources dealing explicitly with service-oriented architecture and cloud computing, acknowledging that service orientation has likely become a prevalent concept in most EA practices and that EA practitioners increasingly embrace the cloud as a natural extension of the enterprise architecture and thus associate it closely with what actually happens in architectural practice (cf. Berneaud et al., 2012).

All in all, we believe our approach of applying bibliometric analysis to EA literature, coupled with an in-depth, qualitative research investigation, is a unique way to capture the state of the art in the research area and, as indicated, offers ideas and advice for researchers and practitioners alike. With this in mind, our findings should assist those who wish to come to grips with the complex field of EA research, and equally those who will act as explorers of EA management in the future.

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Editor's Note: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the article on the Web, can gain direct access to these linked references. Readers are warned, however, that:

1. These links existed as of the date of publication but are not guaranteed to be working thereafter.
2. The contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
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APPENDIX A: BIBLIOGRAPHY OF DOCUMENTS USED FOR BIBLIOMETRIC ANALYSIS

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ABOUT THE AUTHORS

Daniel Simon is a Ph.D. student with the Department of Information Systems and Information Management at the University of Cologne, Germany. He is also an Enterprise Architect with a large insurance enterprise, following several years of work as a Consultant specializing in enterprise architecture management and IT portfolio management. He is TOGAF 9-certified and has gained practical experience in several industries and within different company departments in Germany and the United Kingdom. His recent work on application portfolio management has been published in *Communications of the Association for Information Systems*.

Kai Fischbach is a Full Professor and Chair in Information Systems and Social Networks at the University of Bamberg. His research focuses on integrated information systems, enterprise systems, social and economic networks, and the design of efficient information exchanges. His articles have appeared in *Journal of the Association for Information Systems*, *Communications of the Association for Information Systems*, *Electronic Markets*, *Communications of the ACM*, *Business and Information Systems Engineering*, and other journals.

Detlef Schoder is a Full Professor and Chairman of the Department of Information Systems and Information Management, as well as Director at the Institute for Broadcasting Economics at the University of Cologne, Germany. His work appeared in *Journal of Marketing, Journal of Product Innovation Management, Journal of the Association for Information Systems, Communications of the Association for Information Systems, Electronic Markets, Communications of the ACM*, as well as in transfer-oriented outlets including *Wall Street Journal, MIT Sloan Management Review* and *Harvard Business Review*. Detlef Schoder was appointed reviewer to the German Parliament's lower house for e-commerce issues and consulted the European Commission. He is recipient of numerous academic and industry-related awards and holds patents for IT-enabled individualized media innovations.

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